Factors Affecting Moisture Absorption in Polymer Composites
Part I: Influence of Internal Factors

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ABSTRACT

The influence of internal factors like the fibre volume fraction and its orientation to the diffusion path on the moisture absorption trends of both the permeable (Jute-Epoxy) and the impermeable types (glass-epoxy) of composites were studied. The equilibrium moisture level (Mm) and the diffusion coefficient (D_c) of the glass-epoxy composite decreased as expected, with an increase of the glass fibre fraction (V_f) and its orientation (α), while those of the Jute-epoxy composite (ie M_m' and D_c') were found to increase with an increase in the resin impregnated jute fibre fraction (V_f') and remain practically uninfluenced by the variations in the fibre orientation angle.

These observed trends were explained in terms of typical fibre permeabilities and the diffusion paths preferred by the moisture in these composites. A term called "diffusivity index (D_I)" was introduced to quantify the relative permeabilities of polymer composites to moisture.

INTRODUCTION

MOISTURE KNOWN TO DIFFUSE INTO WELL FABRICATED AND COMPACT polymer composites, by a Fickian diffusion process, is influenced mainly by two types of factors, viz, the internal (fibre volume fraction and its orientation) and the external (relative humidity and temperature) factors, the fibre nature (ie permeable or impermeable) forming an implied but very significant internal factor. The two major external factors are the ambient temperature (T) and the relative humidity (ϕ). The permeability of an overall composite is hence decided by that of the fibre. While the absorption trends of these two types of composites can be similar though different in magnitude under the influence of the external factors, their response to the internal fac-

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tors will be totally different due to the significant role played by the respective fibres.

Expressions relating the composite diffusion coefficient to the fibre fraction and its orientation have been given by investigators like Shen and Springer [1]. However no such work was reported in respect of permeable fibre composites by other investigators. Rao et al [2] for the first time presented a comprehensive moisture absorption analysis in a jute-epoxy composite. Basing their analysis on a resin modified (or resin impregnated) fibre phase in the composite, they derived expressions to relate the composite diffusion coefficient (D_c') to that of the resin impregnated fibre phase (D_f') and its volume fraction (V_f') in the composite. They presented a method of evaluating V_f' for such composites. These authors have further showed [3] that a Fickian diffusion model is equally valid even to this type of composite, provided adequate precaution was taken to fabricate compact composite specimens. Subsequently Rao [4] investigated the moisture absorption characteristics of jute-epoxy composite, vis-a-vis a glass-epoxy composite and suggested technoeconomically viable methods of reducing the moisture absorption levels in the former.

In this paper, the authors present the moisture absorption data obtained on jute and glass-epoxy composites, under the influence of identical internal factors. They describe the observed dissimilarities in their behaviour in terms of different composite schematic models depicting the typical flow paths in both types of materials, and discuss the relative composite permeabilities through the introduction of a term called the diffusivity index.

THEORY

General

Shen and Springer [1] presented an expression for the fractional moisture absorption (G) in a graphite epoxy composite as

$$G = \frac{M}{M_m} = 1 - \frac{8}{\pi^2} \sum_{j=0}^{\infty} \frac{\exp\left[-(2j+1)^2 \pi^2 (D_c t/h^2)\right]}{(2j+1)^2} \tag{1}$$

Which can be simplified for all practical purposes as

$$G = 1 - \frac{8}{\pi^2} \exp\left(-D_c t/h^2\right)\pi^2 \qquad \text{for } \frac{D_c t}{h^2} > 0.05 \tag{2}$$

$$G = \frac{4}{\pi}\left(\frac{D_c t}{h^2}\right)^{1/2} \qquad \text{for } \frac{D_c t}{h^2} < 0.05 \tag{3}$$

Equation (3) being linear can be conveniently rearranged to compute the composite diffusion coefficient as,

$$D_c = \pi \left(\frac{h}{4M_m}\right)^2 \left(\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}}\right)^2 \tag{4}$$

Rao et al [3], showed that a modified version of equation (2) can be effectively used to describe the Fickian diffusion in jute-epoxy composites, as

$$F_s = \frac{M}{M_m'} = 1 - \frac{8}{\pi^2} \left[\frac{1}{\exp \ln (D_c' t/h^2)\pi^2}\right] \tag{5}$$

exp

They showed that very good correlations existed both under the influence of varied external (T) as well as internal (V_f') factors, between theory and experimental data, as shown by the plots between F. and $\ln(D_c' t/h^2)$.

Modified Absorption Theory for Jute-Epoxy Composites

Rao et al [2], through an order of magnitude approach showed that the diffusion coefficient of the resin impregnated fibre phase (D_f') is far far greater than that of the resin (D_r) and presented the following expression relating the composite coefficient (D_c'),

$$D_c' = V_f' D_f' (\cos^2\alpha + K_p \sin^2\alpha) \tag{6}$$

where $K_p = D_{22}'/D_{11}'$

Shen and Springer earlier gave the following expression for graphite-epoxy composites

$$D_c = D_r (1 - V_f)(\cos^2\alpha + \frac{D_{22}}{D_{11}} \sin^2\alpha) \tag{7}$$

The coefficient of $\sin^2\alpha$ term in both equations above is the ratio of transverse to longitudinal diffusion coefficients (Figure 1). The basic difference between Equations (6) and (7) arises due to the following conditions

glass-epoxy	$D_r >> D_f$
Jute-epoxy	$D_f' >> D_r$

For a practical use of Equations (6) and (7) therefore, the coefficients of $\sin^2\alpha$ term have to be evaluated experimentally. These equations clearly indicate the influence of the internal factors on the composite diffusivity.

EXPERIMENTAL PROCEDURE

Commercial grade continuous jute fibres of about 1mm diameter and 8 end E-glass rovings were used along with a laminating grade epoxy system (LY

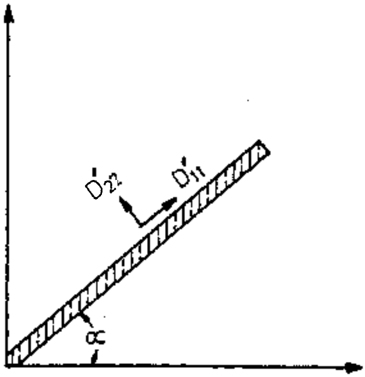

figure 1. Fibre orientation in a permeable fibre polymer composite showing components of composite diffusion coefficient.

556 resin with HT 972 hardener, of Ciba Geigy) to prepare unidirectional test laminates of 2mm thick. Details of preparation of specimens with different volume fractions and their calculation were given elsewhere [3]. Specimens with different fibre orientations were made using a complex procedure. For this, the laminates were cut into 25mm × 25mm x 2mm size, carefully stacked and glued together 12 in number, using the same matrix epoxy resin, and adequate clamping pressure to ensure a void free composite cube of 25mm x 25mm x 25mm size. The cubes were then covered with adhesively bonded thin aluminium foils. This ensured that, moisture could only diffuse into the composite on two opposite faces of 25mm x 25mm at a desired angle to the fibres after suitable slicing of the composite cube again into specimens of 25mm x 25mm x 2mm size. By this procedure, specimens of fibre orientation angles 0°, 30°, 45° and 60° were fabricated. The cut square specimens from the test laminate provided the 90° orientation specimens upon blocking their 4-edges with the aluminium foil. These specimens are shown in Figure 2.

Moisture absorption measurements were carried out under water immersion conditions at 313 °K on the specimens with varied fibre fractions (V_f) and fibre orientation angles (α) as described in the earlier work reported by the authors [3].

RESULTS AND DISCUSSIONS

Effect of Fibre Volume Fraction on Equilibrium Moisture Contents

Figure 3 shows the moisture absorption curves for various fibre fractions of jute-epoxy and glass-epoxy composites. Further Figure 4 shows that the equilibrium moisture value (M_m') of the jute composite increases linearly with fibre volume fraction *(Vj)*, while Figure 5 shows that the equilibrium

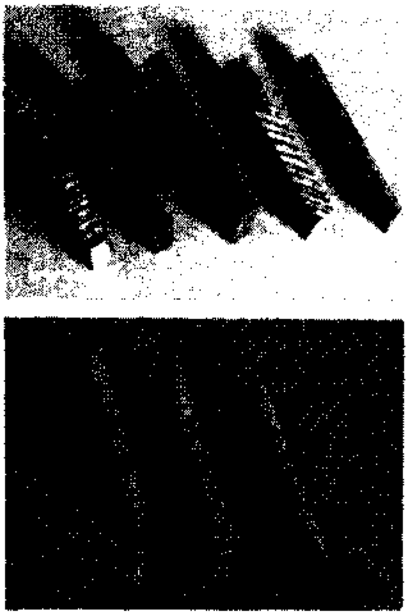

Figure 2. Composite specimens with different fibre orientations, top: jute-epoxy composite, bottom: glass-epoxy composite.

moisture level (M_m) of the glass-composite decreases with increased fibre fraction (V_f).

This result dearly shows that the response of the permeable and impermeable fibre composites to variations in the respective fibre volume fraction are quite opposite in nature, which stems out of the very fibre nature.

Now from Figure 4, the following relationship can be written for the jute composite, viz.,

$$M_m' = 8.6\ V_f' + 3.2 \tag{8}$$

and

$$M_m' = 3.2 \qquad \text{for } V_f' = 0$$

$$M_m' = 11.8 \qquad \text{for } V_f' = 1$$

This indicates that the moisture absorption is the highest for a resin impregnated fibre with no resin surrounding it and the least for an all resin specimen. In the case of the glass-composite, it can be seen that the maximum absorption occurs for an all resin specimen ($V_f = 0$) and the minimum for that with the highest fibre fraction ($V_f = 1$), totally in contrast to the behaviour of the jute composite.

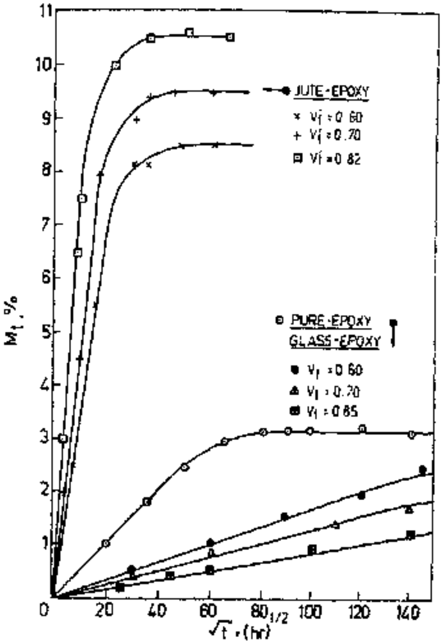

Figure 3. Moisture absorption curves of permeable (jute) and impermeable (glass) fibre composites.

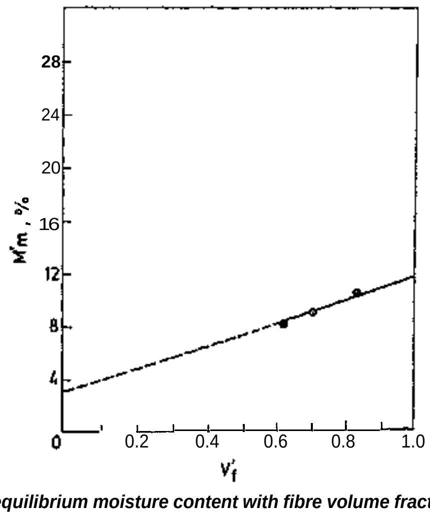

Figure 4. Variation of equilibrium moisture content with fibre volume fraction for jute epoxy composite.

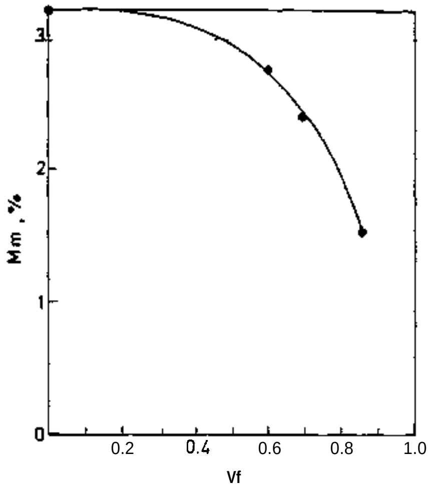

Figure 5. Variation of equilibrium moisture content with fibre volume fraction for glass-ep composite.

Effect of Fibre Volume Fraction on the Composite Diffusion Coefficienf

Figure 6 shows that the overall diffusion coefficient (D_c') of the jute co posite increases with its fibre volume fraction (V_f').This is due to an increas composite permeability as a result of the increased permeable fibre pha Figure 7 further shows that the variation of the jute composite diffusion co

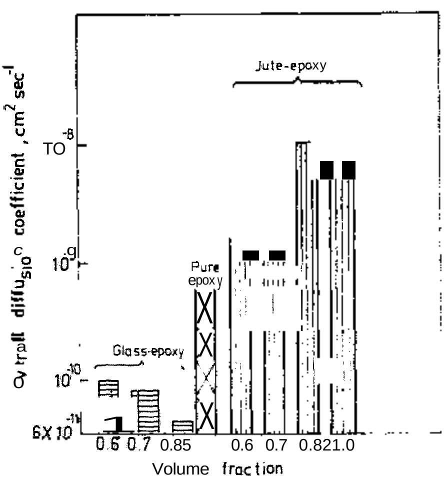

Figure 6. Comparison of diffusion coefficients of jute-epoxyand glass-epoxy composites.

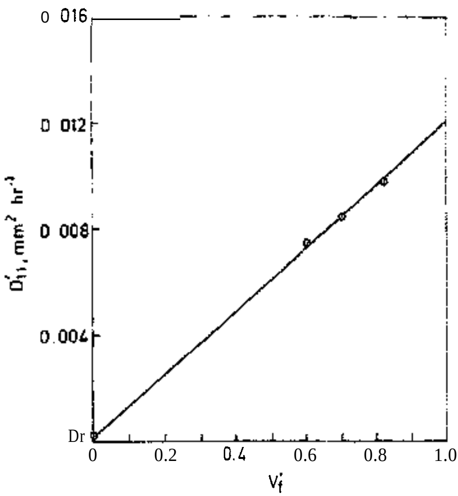

Figure 7. Variation of diffusion coefficient (along fibre direction) with fibre volume fraction for jute-epoxy composite.

ficient along the fibre (D_{11}'), is directly proportional to the fibre fraction, as given below

$$(D_c')_{\alpha=0^\circ} = D_{11}' = 0.012\ V_f' + 0.00029 \tag{9}$$

From Equation (9), it follows that,

$$D_{11}' = 0.01229 \qquad \text{for } V_f' = 1$$

and

$$D_{11}' = 0.00029 = D_r \qquad \text{for } V_f' = 0$$

However, considering the fact that the quantity D_r is negligible as compared to the diffusion coefficient of an all-resin impregnated fibre, equation (9) can for all practical purposes be rewritten as

$$(D_c')_{\alpha=0^\circ} = D_{11}' = 0.012\ VI \tag{9.a}$$

It is seen that, for the glass-composite, the slope of the moisture absorption curves falls as the respective fibre fraction (V_f) is increased (Figure 3), a dear indication that the composite diffusion coefficient decreases (Figure 6) as the glass fibre content is increased. This is an expected trend since it leads to a composite with decreased permeability.

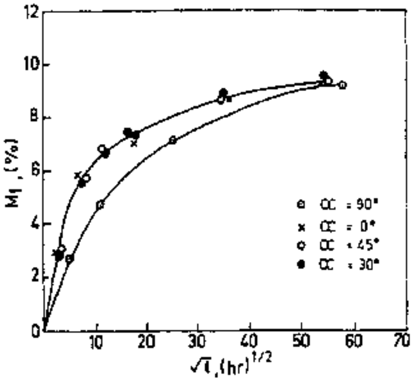

Figure 8. Moisture absorption curves with different fibre orientation angles for jute-epoxy composite.

Effect of Fibre Orientation Angle (α) on the Composite Diffusion Coefficient

Figure 8 and Figure 9 show the moisture absorption curves respectively for the jute-epoxy and glass-epoxy composites, at various fibre orientation angles (0–90°) to the diffusion direction. Figure 8 shows that the moisture absorption curves remain practically unchanged for all the fibre orientation angles of 0°–60°, specimens with fibres placed transversely to the diffusion direction (α = 90°), however indicating a somewhat different curve with reduced slope. The reduced slope of the moisture absorption curve for specimens with α = 90°, can be attributed to the impeding effect, though to a small extent,

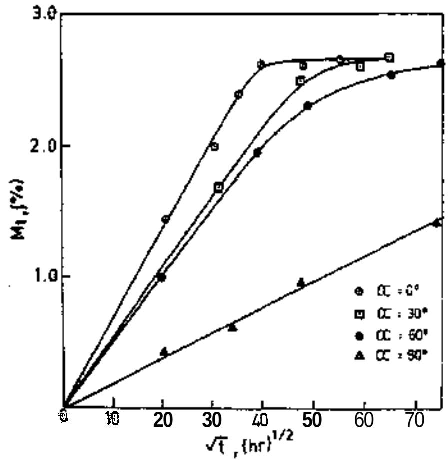

Figure 9. Moisture absorption curves with different fibre orientation angles for glass-epoxy composite.

caused by the transversely oriented fine fibrils constituting the bulk jute fibres.

Now referring to Figure 9, it can be noted that the initial slopes of the moisture absorption curves of the glass-epoxy composite decrease steadily with increased fibre orientation angles, showing that the composite diffusion coefficient decreases as the fibre orientation to the diffusion path is increased.

From the above two figures, the ratios of the transverse diffusion coefficient to the longitudinal diffusion coefficient, are as follows,

Jute-epoxy composite	$(D'_{22}/D'_{11})\ V'_f = 0.7$	$= 0.7$
Glass-epoxy	$(D_{22}/D_{11})\ V_f = 0.7$	$= 0.31$

The diffusion coefficients of the pure resin (D_r) and of the resin impregnated jute fibre (D'_f), are

$$D_r = 0.083 \times 10^{-8}\ \text{cm}^2\ \text{Sec}^{-1}$$

$$D'_f = 3.33 \times 10^{-8}\ \text{cm}^2\ \text{Sec}^{-1}$$

The overall diffusion equations for the jute and glass fibre based epoxy composites $(V_f = V'_f = 0.7)$ are therefore represented as, respectively,

$$D'_c = 2.33 \times 10^{-8}\ (\text{Cos}^2\alpha + 0.70\ \text{Sin}^2\alpha) \tag{10}$$

$$D_c = 0.025 \times 10^{-8}\ (\text{Cos}^2\alpha + 0.31\ \text{Sin}^2\alpha) \tag{11}$$

Figure 10, shows the plots of equations (10) and (11).

Diffusivity Index (D_I) A Measure of Composite Permeability

The foregoing analysis envisages two distinct types of polymer composites, whose diffusivities lie on either side of that of an unreinforced polymer matrix. It is hence appropriate to use a relative diffusivity term "the diffusivity index, D_I", defined as,

$$D_I = \frac{D'_c}{D_r} \text{ or } \frac{D_c}{D_r} \tag{12}$$

so that, a classification based on A values enables one to quickly choose a practically suitable approach, in analysing the diffusion in jute and glass composites with respect to that of the matrix resin. Figure 11 shows the variation of the 'D_I values with respective fibre volume fractions. It can be seen that the D_I value increases from 1 to 22 as the V'_f value of the jute-composite is increased from 0 to 0.82, while the corresponding value decreases from 1 to

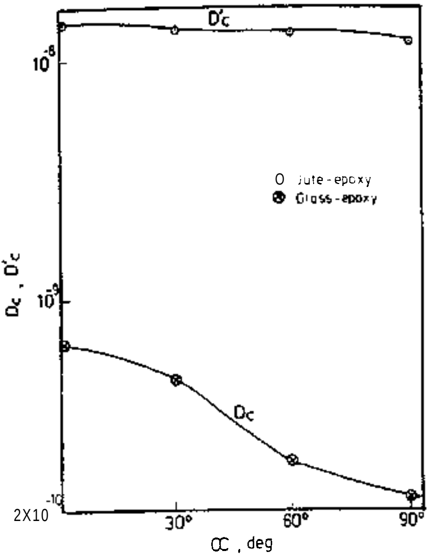

Figure 10. Variation of overall diffusion coefficients of jute-epoxy and glass-epoxy composites with fibre orientation angles.

0.14 as the V_f value is increased for the glass-composite practically in the same range.

From Figure 6, it may be observed that, at a volume fraction of 0.6, the diffusion coefficient of the jute-composite (2 x 10^{-9} cm^2 Sec^{-1}) is an order of magnitude higher than that of the glass-composite (1.5 x 10^{-10} cm^2 Sec^{-1}).

The diffusion coefficient values of the jute-composite obtained from the experiments are, however, much less than what would be expected purely from a consideration of the basic permeabilities of the virgin fibres of jute and glass. This may be attributed to the two following reasons.

(i) The highly porous virgin jute fibres get mostly impregnated with a relatively less permeable (or least permeable) resin phase.

(ii) The high initial slopes of the moisture absorption curves of the jute-epoxy composites, are partly offset by the higher magnitudes of the equilibrium moisture levels, the latter quantity occurring in the denominator of Equation (4), used to calculate the diffusion coefficients.

However, the resulting diffusion coefficient values of the jute-epoxy composites are still high enough to qualify them as permeable type polymer composites, as confirmed from a study of the A values, especially at high fibre-volume fractions. However if the permeability of jute fibres, is brought down by any technoeconomically viable methods, prior to incorporating them in a resin matrix, the A values can be further brought down, if not as close as to those of the glass-composite.

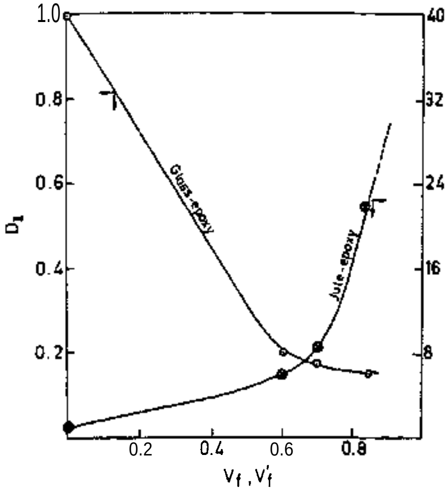

Figure 11. Variation of diffusivity index (D,) of jute-epoxy and gfass-epoxy composites with fibre volume fraction.

Diffusion Paths in Permeable and Impermeable Fibre Based Composites

The dissimilarities noted above in the moisture absorption behaviours of the permeable and impermeable type of polymer composites arise out of the basic permeabilities of these fibres to the moisture.

Figure 13, shows the typical paths followed by the diffusant in these composites. As described by Mehta et al [5], in an impermeable fibre based polymer composite, the moisture takes a distorted path as characterized by the following equation,

$$K = 1/\beta\xi$$

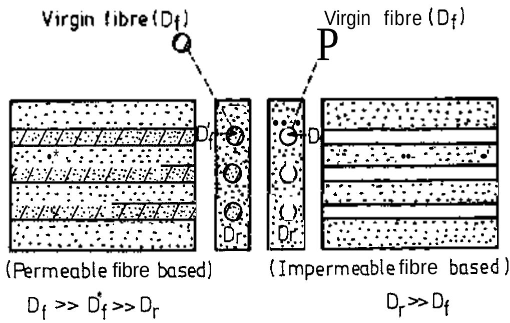

Figure 12. Schematic models of permeable and impermeable fibre polymer composites.

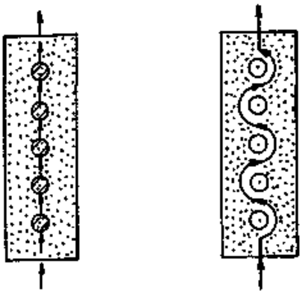

Figure 13. Typical difusion paths in permeable (Figure A) and impermeable (Figure B) fibre polymer composites.

Where the magnitude of K called the "Structure Factor," decides the dependence of the diffusion coefficient on the structure of a given composite. β and 4, respectively represent the tortuosity factor and the polymer chain immobilisation factor. Thus in an impermeable fibre polymer composite, the fibre impedes the diffusion process.

In a permeable fibre based composite, however, it can be seen that, the moisture tends to take a diffusion path through the fibres as they are found to be even more permeable than the matrix itself. Further, the fibre having been Impregnated with the matrix resin, the diffusant finds a continuity of path from the matrix through the fibre.

In such composites, therefore, even when the fibre lie oriented to the diffusion path, insignificant effects are noticed in their moisture absorption characteristics.

CONCLUSIONS

The diffusion coefficient and the equilibrium moisture content of the permeable fibre based polymer composite (Jute-Epoxy), increase with fibre volume fraction, while a totally opposite trend is noticed in the case of impermeable fibre based composites (glass-epoxy).

The fibre orientation to the diffusion direction has an insignificant effect on the diffusion coefficient of the permeable fibre composite, while the corresponding effect is pronounced in the case of the impermeable fibre composite, with the diffusion impeded as the fibre orientation to the diffusion path is increased.

Jute-Epoxy composites exhibit much higher diffusivity index values than the glass-epoxy composites especially at higher fibre volume fractions.

Jute-resin composites were however subsequently modified to reduce their permeability and enhance scope for their practical applications. The techniques of modification, which were found to be technoeconomically viable were reported elsewhere [6].

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Factors Affecting Moisture Absorption in Polymer Composites Part II: Influence of External Factors

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ABSTRACT

The influence of external factors like relative humidity (Ø) and ambient temperature (T) on the moisture absorption behaviour of permeable (Jute-Epoxy) and impermeable (Glass-Epoxy and Graphite-Epoxy) types of composites were reported. The respective equilibrium moisture contents (M_m' and M_m) increased exponentially with relative humidity. The diffusion coefficients of both type of composites (D_c' and D_c) increased with ambient temperature and could be represented by an Arrhenius relationship.

The permeable composite showed a higher exponential power on the relative humidity term than the impermeable composite (2.64 for Jute composite as compared to 2.0 reported by Shen and Springer for a graphite composite) and a lower activation energy for diffusion (0.9×10^3 cal. $mole^{-1}$ for the jute composite as compared to 4.429×10^3 cal. $mole^{-1}$ obtained for a glass composite). These trends were attributed to the fibre permeability leading to different diffusion barriers in such composites.

INTRODUCTION

MOISTURE ABSORPTION IN POLYMER COMPOSITES IS INFLUENCED BY internal (fibre fraction and its orientation) and external (relative humidity and ambient temperature) factors.

Investigators like Shen and Springer [1] reported on the influence of these factors on the moisture absorption in graphite-epoxy composites representing the impermeable type composites. Rao [2] for the first tune investigated the influence of both the factors on the absorption behaviour of a jute-epoxy composite denoting the permeable type composite. Rao et al [3] subsequently reported that, the disparities in the moisture absorption behaviours of both

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class of composites under the influence of the internal factors stemmed out of the very fibre nature.

In this paper, the authors report the influence of external factors on the moisture absorption characteristics (equilibrium absorption and diffusion coefficient), of permeable and impermeable composites by considering respectively the jute-epoxy and the glass and graphite-epoxy composites.

THEORY

Effect of Ambient Temperature (T)—The Arrhenius Relationship

Any activated process can be conveniently characterised by an Arrhenius relationship. For the composites under consideration, the temperature dependence of respective composite diffusion coefficients can be represented as,

$$D_c = D_o \exp^{-E_d/RT} \quad \text{impermeable composite} \tag{1}$$

$$D_c' = D_o' \exp^{-E_d'/RT} \quad \text{permeable composite} \tag{2}$$

Where the respective diffusion coefficients can be calculated using the following expressions,

$$D_c = \pi \left[\left(\frac{h}{4M_m} \right)^2 \left(\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}} \right)^2 \right] \tag{3}$$

$$D_c' = \pi \left[\left(\frac{h}{4M_m'} \right)^2 \left(\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}} \right)^2 \right] \tag{4}$$

A plot between the diffusion coefficient and $1/T$, will then be helpful in evaluating the pre-exponential factor (D_o or D_o') and the activation energy for diffusion (E_d or E_d'). That the composite diffusion coefficients increase with temperature readily indicates that, equilibrium absorption conditions are reached faster, the higher the temperature is, since the saturation times (t_m or t_m') are related to respective diffusion coefficients inversely as reported by Shen and Springer [1].

Effect of Relative Humidity 0

Shen and Springer reported that, the equilibrium moisture content of a composite is related exponentially to the relative humidity term and accordingly, the following two expressions may be written to represent this dependence.

$$M_m = a\, \varnothing^b \quad \text{impermeable composite} \tag{5}$$

$$M_m' = A\, \varnothing^B \quad \text{permeable composite} \tag{6}$$

The constants (a,b) and (A,B) have to be evaluated experimentally.

EXPERIMENTAL PROCEDURE

Commercial grade jute-fibres of 1mm diameter and 8 end E-glass rovings were used with a laminating grade epoxy system (LY 556 resin and HT 972 hardener, supplied by Ciba Giegy), to prepare unidirectional composite laminates of 2mm thickness. Details of laminate fabrication and specimen preparation were reported elsewhere [3].

Moisture absorption curves were obtained for jute and glass composites by exposing the specimens to various relative humidity conditions (32%, 76%, 92% and 98%) simulated as per the specications of ASTM E-104 using super saturated salt solutions.

To study the temperature effect, specimens were immersed in distilled water at different temperatures (298 °K, 313 °K and 333 °K) and moisture absorption data obtained by weight difference technique as reported earlier [3]. All these data were obtained on specimens with respective volume fractions of 0.7, for both type of composites. Composite diffusion coefficients have been calculated using Equations (3) and (4).

RESULTS AND DISCUSSIONS

Effect of Ambient Temperature (T)

Figure 1 shows the moisture absorption curves for the jute composite at different ambient temperatures. The slopes of the curves increase as the temperature is increased, while the equilibrium absorption levels remain

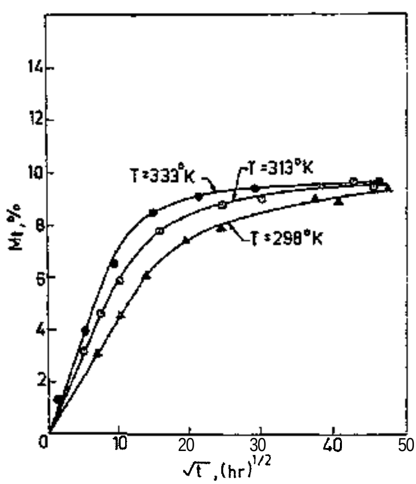

Figure 1. Moisture absorption curves of jute-epoxy composite at different temperatures (V_f = 0.70).

essentially the same. The Arrhenius plot is shown in Figure 2. The diffusion kinetics parameters as calculated from the figure are as follows,

$$D_o' = 1 \times 10^{-3}\ cm^2\ sec^{-1}$$

$$E_d' = 0{,}9 \times 10^3\ cal\ mole^{-1}$$

The temperature dependence of the composite diffusion coefficient (D_c') can therefore be written as,

$$D_c' = 1 \times 10^{-3}\ exp^{-0.9} \times 10^3/RT \tag{7}$$

Figure 3 and Figure 4 show the data for the glass-epoxy composite under the influence of different temperatures. The kinetics parameters for this composite are,

$$D_o = 1 \times 10^{-1}\ cm^2\ sec^{-1}$$

$$E_d = 4.429 \times 10^3\ cal.\ mole^{-1}$$

The Arrhenius relationship for the glass composite is therefore,

$$D_c = 1 \times 10^{-1}\ exp^{-4.429} \times 10^3/RT \tag{8}$$

Comparison of Equations (7) and (8) shows that, the jute composite has a lower activation energy than the glass composite, indicating a weaker diffu-

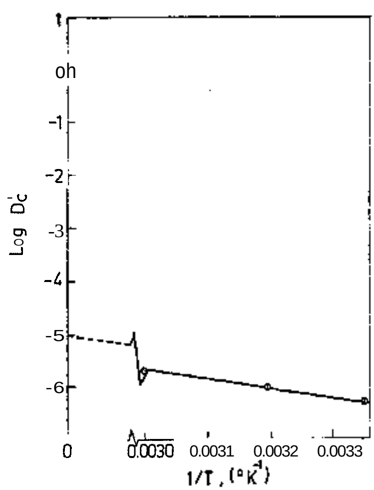

Figure 2. *Arrhenius relationship for the jute-epoxy composite* $(V_f' = 0.70)$.

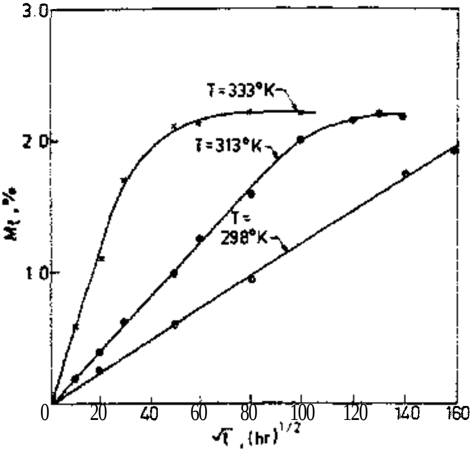

Figure 3. Moisture absorption curves of glass-epoxy composite at different temperatures (V_f' = 0.70).

sion barrier in this composite. This largely accounts for the high diffusion coefficient values observed in this composite.

Effect of Relative Humidity 0

The effect of relative humidity on the moisture absorption of the jute composite is shown in Figure 5 and Figure 6 shows a plot of log (M_m') against log (0). The following equation can therefore be obtained from this figure.

$$M_m' = 0.00003\ (\varnothing)^{2.64} \tag{9}$$

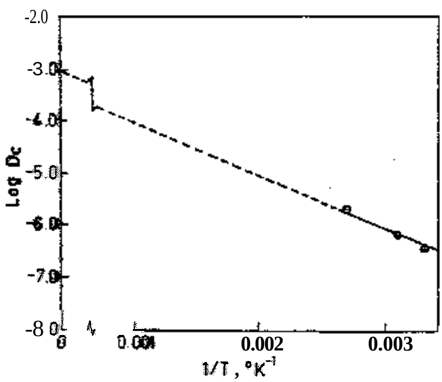

Figure 4. Arrhenius relationship fer the glass-epoxy composite (V_f' = 0.70).

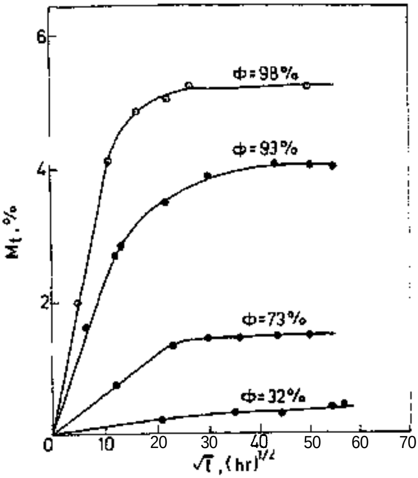

Figure 5 *Effect of relative humidity on the moisture absorption characteristics of jute-epoxy composite* ($V_f' = 0.70$, $T = 298°K$).

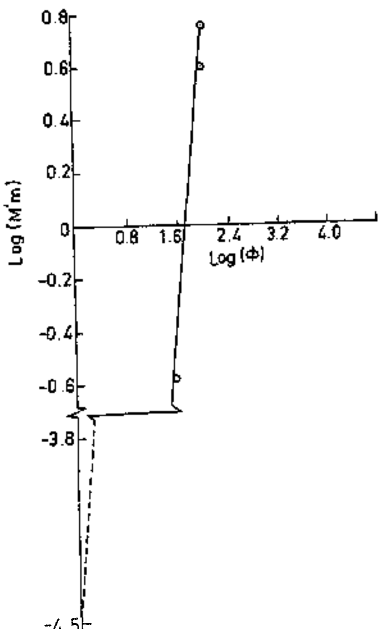

Figure 6. *The relationship between* log (M_m') *and* log (Φ) *for jute-epoxy composite* ($V_f' = 0.70$, $J = 298°K$).

Table 1. Diffusion characteristics of jute-epoxy and glass-epoxy composites—overall comparison.

Diffusion Property	Epoxy Resin	Jute-Epoxy Composite ($V_f' = 0.7$)	Glass-Epoxy Composite ($V_f = 0.7$)
M_m (%)	3.2	8.5	2.0
D_c' or D_c	8.3×10^{-10}	4.4×10^{-9}	9.2×10^{-11}
E_d' or E_d (cal. Mote")	—	0.9×10^{3}	4.42×10^{3}
DO or D_o ($Cm^2 Sec^{-1}$)	-	1×10^{-3}	1×10^{-1}
Fickian Model	Applicable	Applicable	Applicable

Earlier Shen and Springer [1] gave the following expression for a graphite-epoxy unidirectional composite,

$$M_m = 0.0004\ (\varnothing)^{10} \tag{10}$$

Comparison of Equations (9) and (10) indicates that, the permeable fibre (jute) composite is characterised by a higher exponential power on the relative humidity term, which accounts for the high moisture absorption levels in such composites. This is also confirmed by the data on glass-epoxy for which Bonniau and Bunsell [41 obtained the expression,

$$M_m = 0.01\ (\varnothing)^{1} \tag{11}$$

Table 1, shows the important diffusion characteristics of the jute and glass epoxy composites subjected to identical conditions of exposure.

CONCLUSIONS

Temperature dependence of the diffusion coefficients of permeable and impermeable fibre composites can be represented by an Arrhenius relationship.

Equilibrium moisture contents of both type of composites are influenced alike by the changes in relative humidity. The low activation energy of diffusion in the jute composite and a high exponential power on the relative humidity term indicate a weaker diffusion barrier in the permeable composite and largely account for the faster diffusion process in such composite.

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